MODELS FOR CONDUCTING PROGRESS AND MILESTONE REVIEWS: IMPLEMENTATION OF CMMI LEVEL 2 SPECIFIC PRACTICES FOR SMALL AND MEDIUM-SIZED SOFTWARE DEVELOPMENT ORGANIZATIONS

BY

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This thesis, written by **OSAMAH MOHAMMED AL-DHAFER** under the direction of his thesis adviser and approved by his thesis committee, has been presented to and accepted by the Dean of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN COMPUTER SCIENCE**.

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Dedicated To My parents

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THESIS ABSTRACT

NAME: Osamah Mohammed Al-Dhafer

TITLE OF STUDY: Models for Conducting Progress and Milestone Reviews: Implementation of CMMI Level 2 Specific Practices for Small and Medium-Sized Software Development Organizations

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The context of this research is software process improvement in small and medium-sized software development organizations, particularly those implementing a specific practice SP 1.6: "conduct progress review" and SP 1.7 "conduct milestone review" of the CMMI level 2 project monitoring and control process area. In this research, our objective is to implement the CMMI level 2 specific practice SP 1.6: "conduct progress review" and SP 1.7 "conduct milestone review". In addition, this research aims to help small and medium-sized software development organizations by designing a process map for SP 1.6 & SP 1. 7 with related templates and checklists. The method of collecting data is based on the extensive literature

review by selecting papers that are most relevant to our objectives and interviewing some experts. This method is used to clear the picture of different views of implementation. It will meet our objectives by minimizing the gap between the industry and the academic fields. After analyzing the collected data, we have proposed two models for two specific practices SP 1.6 and SP 1.7. Each model is divided into core stages, and different activities associated with each stage are indicated. The proposed models are evaluated by expert review process. In addition, initial evaluation of these models has been conducted through an expert panel review process. Based on the results and evaluation of the proposed model, small and medium-sized software development organizations will find the models easy to follow, useful, efficient, and customer satisfactory. Moreover, our proposed models are going to assist the small and medium sized software development organizations in improving the software process and lead to the production of high-quality software products. The applicability of the model in the industry by conducting multiple case studies is still needed to gain rich insights.

ملخص الرسالة

الاسم الكامل: أسامة محمد الظافر

عنوان الرسالة: نماذج اجراء مراجعة التقدم المحرز والعلامات المرحلية: تطبيق تكامل نموذج نضوج المقدرة المستوى الثاني

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سياق هذا البحث هو تحسين تطوير عملية البرمجيات في المنظمات المتخصصة بتطوير البرمجيات الصغيرة والمتوسطة الحجم، خصوصا تلك التي تنفذ ممارسة الاجراء المحدد 1.6: " إجراء مراجعات التقدم المحرز" والاجراء المحدد 1.7: "إجراء مراجعات العلامات المرحلية" في نموذج تكامل نضوج المقدرة للمستوى الثاني ضمن منطقة عملية "رصد المشاريع والتحكم".

في هذا البحث، هدفنا هو تنفيذ اجراء مراجعة التقدم المحرز والعلامات المرحلية للمشروعات المنفذة بواسطة الشركات الصغيرة والمتوسطة. وبالإضافة إلى ذلك، يهدف هذا البحث إلى مساعدة المؤسسات الصغيرة والمتوسطة الحجم على تطوير البرمجيات من خلال تصميم خريطة عملية لكل من الاجراء المحدد 1.6 والاجراء المحدد 1.7 والقوالب ذات الصلة لكل منهما.

الأسلوب المتبع للوصول للنتائج هو المسح الادبي المستفيض عن طريق اختيار الأوراق الأكثر ملاءمة من اجل الحصول على المنشورات التي تساهم في تحقيق الأهداف المنشودة، وأيضا عن طريق مقابلة بعض الخبراء .وتستخدم هذه الطريقة لاستيضاح الرؤية من وجهات نظر مختلفة عن التنفيذ. هذه الطريقة سوف تحقق أهدافنا عن طريق التقليل من الفجوة بين المجالات الأكاديمية والصناعية. وبعد تحليل البيانات التي تم جمعها، اقترحنا نموذجين للإجراءين المحددين 1.6 و1.7. وينقسم كل نموذج الى مراحل أساسية، وأيضا أنشطة مختلفة مرتبطة بكل مرحلة.

وبالإضافة إلى ذلك، سيتم إجراء تقييم أولي لهذه النماذج عن طريق عرض النتائج على خبراء في نفس المجال. وبناء على نتائج وتقييم النموذج المقترح، منظمات تطوير البرمجيات الصغيرة والمتوسطة الحجم ستتمكن من استخدام نماذج سهلة التتبع، مفيدة، فعالة، ومرضية للعملاء. وعلاوة على ذلك، النماذج المقترحة سوف تساهم في مساعدة مؤسسات تطوير البرمجيات الصغيرة والمتوسطة الحجم في تحسين عملية البرمجيات وتؤدي إلى إنتاج برمجيات عالية الجودة. بالرغم من ذلك، لا تزال هناك حاجة لتطبيق النموذج في النواحي الصناعية من خلال إجراء دراسات حالة متعددة للحصول على معلومات أكثر.

CHAPTER 1

INTRODUCTION

1.1 Overview

With the rapidly growing importance of software in our daily lives, the quality of software has become a critical part of the software industry [5]. Since most of the problems are caused by processes [6], much attention has been given to the software process improvement (SPI) concept. The main motivation behind the SPI initiative is that the quality of a product is strongly influenced by the quality of the underlying software process[7].

SPI methodologies are based on assessing organizational capabilities to produce software with higher quality [8]. Over the last decades, many SPI models have been published, and their success has been recognized, even though the literature clearly indicates that SPI implementation faces various problems. Niazi et al. [9] conducted an empirical study in order to generate critical success factors for SPI implementation. Sulayman et al. [10] investigated SPI success factors

for small and medium-sized web companies. In general, one of the main demotivators of support for SPI models is lack of resources [11] . The main focus of SPI is the process and how we can improve it. Its aim is to improve the quality of software by enhancing the processes of development in organizations. It helps companies mature their processes and meet their objectives by producing products on time and within budget, minimizing developmental costs, and improving customer satisfaction.

In order to achieve higher quality, many models or frameworks of SPI control and optimize the processes of software development, such as the capability maturity model (CMM) [12], the predecessor model of the capability maturity model integration (CMMI)[5], the software process improvement and capability determination (SPICE) [13], which is specified in ISO/IEC 15504, Six Sigma[14], and Bootstrap[15]. These models help assess and measure the processes and practices that should be implemented in the organization. In addition, organizations use these models to determine the level of maturity of the process. Moving between these levels of process maturity needs more effort and time, roughly between 15 and 21 months[16].

However, most of these SPI models were perceived to be oriented toward large organizations. Not much attention has been given to small and medium-sized software development organizations. The CMMI model is one of the SPI models that target large enterprises [17, 18, 19], Because of this , small and medium-sized enterprises (SME) encounter some difficulties associated with the cost, time, and

resources required to implement these models [20, 21]. Adopting these models in SMEs is very difficult because their activities mainly target large enterprises [22, 20, 23]. In addition, the CMMI model identifies the best practices to improve the processes in an organization, but it answers "what" organizations should implement instead of "how" it should be implemented [24].

CMMI is one of the latest and popular models of SPI[25]; It is an approach to process improvement that helps organizations' processes become more effective. It can be used as guidelines for achieving higher-quality processes and providing assessment and measurement for these processes. The CMMI model supports two views on process improvement in order to implement CMMI: staged and continuous representations [26]. With staged representation, CMMI provides a fixed way of process improvement and measures the maturity of an organization from level 1 as an initial level until level 5, which is an optimized process.

At each level, the organization adopts a specific set of process areas, which is a set of related practices. At maturity level 2, the organization tries to plan and execute the processes of the project in accordance with the policy. In addition, the organization should adopt the seven process areas along with the first two generic goals. The project monitoring and control (PMC) process area is one of the important process areas at level 2, and it contains two specific goals or 10 specific practices in total. The PMC process area has two specific goals: the first one is to monitor the project against the plan, and the second is to manage corrective action to closure. In addition, organizations should adopt the first two generic

goals: achieve specific goals and institutionalize the managed process. The first specific goal contains seven specific practices, and the second specific goal contains three specific practices.

1.2 Motivation

Based on [24] the problem with SPI is the lack of an efficient strategy in implementing the available models or standards. Many studies have been conducted to identify the importance of the practices or which one of them the organization should implement instead of clarifying the "how" statement in implementing these practices efficiently. In addition, several studies showed that SPI models target large enterprises. Because of that, SMEs encounter some difficulties associated with the cost, time, and resources required in implement them [20, 21]. Adopting these models in SMEs is very difficult because their activities mainly target large enterprises [22, 23]

We are limiting our research on CMMI for development (CMMI-DEV) model version 1.3 because CMMI is the latest SPI model that provides the best practices for product, service development and maintenance, and widespread use. The main thing about CMMI is specifying what process areas the organization should give attention to, but CMMI does not talk about how the organization should behave in order to implement these process areas. Based on observation, when SMEs start improving their processes based on the CMMI model, they implement level 2 process areas [27, 28].

At CMMI level 2, two of the seven process areas, project planning and project monitoring and control, are considered core CMMI process areas [29]. The PMC process area shows more importance. It can be seen as the way to success in managing a project [29].

We select two out of the 10 specific practices in the PMC process area, which are SP 1.6 and SP 1.7. The progress review can be seen as a channel of communication between members of the project and can help the project manager make the right decision based on the priority information that is gathered. The milestone and progress review share their importance. The milestone of the project can be seen as mini-goals that help achieving the main goals of the project.

Based on the [30, 31], the categorization of specific practices based on their perceived value is shown in Figure 1.1. We can clearly see that SP 1.6 and SP 1.7 were categorized as having a "high" perceived value, with a score of more than 70%. The categorization is based on six SMEs' software development.

Project monitoring and control		
Perceived value	Specific Goal 1	Specific Goal 2
High	SP1.6-1 SP1.7-1	SP2.1-1 SP2.2-1
Medium	SP1.1-1 SP1.2-1 SP1.3-1 SP1.5-1	–
Low	SP1.4-1	SP2.3-1

Figure 1.1: Categorization of PMC practices based on perceived value

The importance is declared empirically by using a questionnaire to collect

data from 46 software development practitioners in two countries [27], The result showed that SP 1.6 and SP 1.7 are important practices in the PMC process area. Specifically, SP 1.6 has more perceived value than SP 1.7. In Figure 1.2, SP 1.6 is cited as either high or medium 40 times out of 46 practitioners. We extract only the high and medium ranks and summarize them to see the total opinions about specific practices by adding the high and medium. In addition, SP 1.6 has significant interactions with SP 1.7, and both of them can be done at the same time[5] .

	Malaysia		Vitnam		Malaysia + Vitnam		
Specific Pracice	HIGH	MEDIUM	HIGH	MEDIUM	HIGH	MEDIUM	Medium + High
SP 1.1-1	10	8	5	15	15	23	38
SP 1.2-1	8	9	5	16	13	25	38
SP 1.3-1	10	8	10	11	20	19	39
SP 1.4-1	7	11	7	13	14	24	38
SP 1.5-1	5	9	8	12	13	21	34
SP 1.6-1	9	10	9	12	18	22	40
SP 1.7-1	10	8	8	11	18	19	37
SP 2.1-1	10	8	10	9	20	17	37
SP 2.2-1	9	12	10	12	19	24	43
SP 2.3-1	10	10	8	12	18	22	40

Figure 1.2: PMC practices with "value" cited by Malaysian and Vietnamese practitioners.

In general, tracking the progress of the project is one of the five critical success factors in software projects [32]. In small organizations, measuring progress and conducing reviews are considered the main challenges [33, 23], and our objective is to help small and medium-sized software development organizations implement SP 1.6 and SP 1.7. These specific practices mainly help understand the progress of the project and provide the ability of corrective action to be taken at a specific time.

1.3 Objective

The objective of our work is to implement CMMI specific practices, SP 1.6 (i.e., conduct progress reviews) and SP 1.7 (i.e., conduct milestone review). The major objectives of this research are the following:

- Describing a model of SP 1.6 in order to effectively review the progress of the project.
- Describing a model of SP 1.7 in order to e effectively review the milestone of the project.
- Evaluating a model of SP 1.6 through SPI domain experts.
- Evaluating a model of SP 1.7 through SPI domain experts.

In order to meet these objectives, we formulate the research questions in accordance with the technology acceptance model (TAM) [34, 35, 36]

RQ1 How can we implement CMMI Level 2 SP 1.6 and SP 1.7?

RQ2 What is the perceived "ease of learning and ease of use" of the proposed models for SP 1.6 and SP 1.7 models?

RQ3 What is the "perceived usefulness" of the proposed models for SP 1.6 and SP 1.7 models?

RQ4 What is the "perceived applicability" of the proposed models for SP 1.6 and SP 1.7 to small- and medium-sized software development organizations?

1.4 Research Contribution

Our contributions of the thesis are theoretical and practical:

- Identifying different models of reviewing the project through the literature and interviewing some panel process experts.
- In this research, we have proposed two models of progress and milestone review, and designed some templates to help SME software development organizations implement the proposed models of progress and milestone review.
- We have evaluated the proposed models by asking some panel process experts about the models and their applicability of implementation.
- We have compared the proposed models and the other models found in the literature and interview in terms of: specific criteria, activity, adopting subpractices of SP 1.6 and SP 1.7.

1.5 Outline

This thesis is composed of five parts, presented through five chapters. Chapter 2 provides a brief background and literature review, where CMMI and its representations are described and SME software development organizations' challenges and features are clarified.

Chapter 3 presents the research methodology that we followed and the steps that we took to get the current findings. Chapter 4 presents and discusses the

findings from the present study. It provides the different models of implementing a progress review based on the literature and the interview data. In chapter 5, the discussion about the evaluation is illustrated based on the results of a survey sent to some experts in SPI. Chapter 6 discusses the limitation of the work and the conclusion, which summarizes the findings. This chapter also provides some suggestions for future research in this field of study .

CHAPTER 2

BACKGROUND

2.1 Software and Quality

Nowadays, software is becoming a significant part in products and services; its importance makes the researchers more interested in understanding the best way of getting them in an effective manner. In addition, the quality of the software has a great impact on any organization and it still an issue of building any software.

2.2 Process

The process is defined as "a course of action to be taken to perform a given task "[37]. A software process is an environment that contains a set of resources that are capable to manage a set of tasks by using suitable methods and practices in order to get a software product that meets the customers requirements [38]. Processes cause most of the problems that might happen rather than by people [6], this motivates the practitioners in looking to the best practices to mature

their processes; process is mature if it is defined and documented in detailed description. The process is represented by a model or process map which describes flow of activities and tasks pictorially. The process map consists of the input of the activity and the output. The process also consists of check-lists and templates that help understand the process.

2.3 Software Process Improvement (SPI)

SPI is a key for developing a software with higher quality. SPI is assessing and modifying the methods of current software process in software development organizations [39]. The main focus of SPI is the process and how we can improve the process. Its aim is increasing the quality of the software by enhancing the processes of the development in the organizations. It helps the companies in maturing their processes and achieving their objectives by producing the products on time and budget, and minimizing the development costs. SPI helps the companies choosing the right processes that sustain the consistency with trained staff and objectives. Many researches had been done in SPI field as mentioned [40]. There are models that used in SPI such as CMMI, Six Sigma, and ISO 9001 Standard etc.

2.4 Capability Maturity Model Integration (CMMI)

The main objective of SPI is defining and enhancing the processes of software organization. To achieve this objective, we are using CMMI, which is "a reference model of mature practices in a specified discipline, which is used to improve and appraise a group's capability to perform that discipline". CMMI model identifies the best practices to improve the processes in an organization, but it answers "what" the organizations should implement instead of "how" they should be implemented[24].

CMMI model has twenty-two process areas, which they belong to four categories: process management, project management, engineering, and support. The four categories help in understanding and describing the high-level interactions between the process areas. At each process area, there are some specific practices that need to be implemented. Every process area contains a set of specific goals, and these goals are implemented by specific practices related to that process area. In addition, CMMI categorizes the process areas by maturity level into two representations.

2.4.1 Continuous Representation

The continuous and staged representation have the same number of process areas, but the difference between them is the way or the order of implementing these process areas. The continuous representation has no maturity level for the process

areas as shown in figure 2.1. It provides flexibility of implementing the CMMI model based on the process area that is essential for the organization, and meets their business objectives. In the continuous representation, there are capability levels that used to determine the progress of process area for an organization. Those six levels are optimizing, quantitatively managed, defined, managed, performed and incomplete. A capability level contains a set of practices either specific or generic for a process area that help improving the processes of organization related to that area.

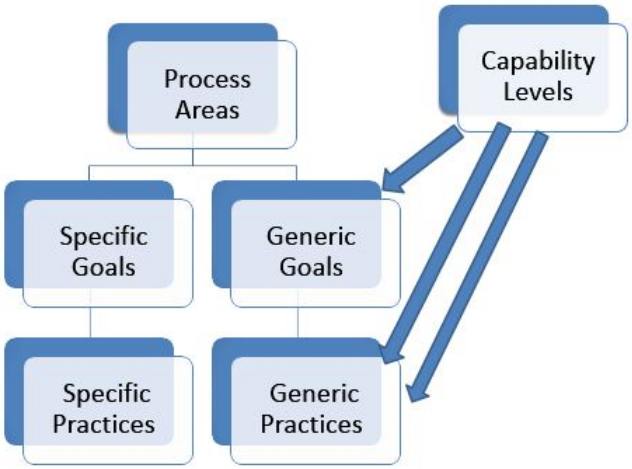

Figure 2.1: Continuous Representation

2.4.2 Staged Representation

The best used is staged representation which based on categorizing the process areas into five levels of maturity. These levels provide specific order for approaching process improvement. The organization can be placed at specific maturity level if the specific and generic goals that apply each set of process areas are achieved.

These five levels are optimized, quantitatively managed, defined, managed, and initial. In Figure 2.2, the structure of the staged representation of CMMI is shown.

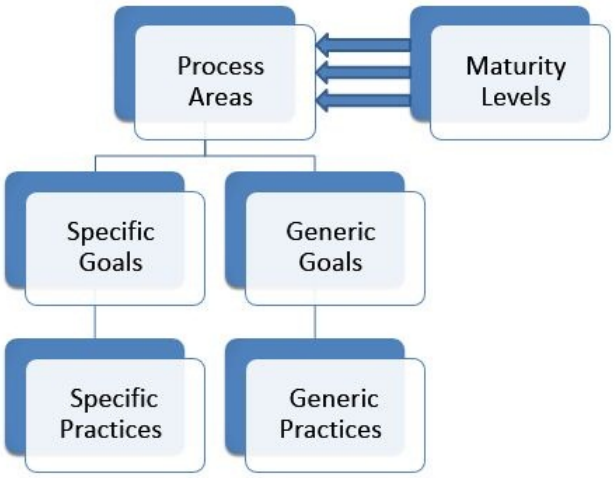

Figure 2.2: Staged Representation

2.4.3 Maturity Level 2: Managed

The level of maturity of processes in an organization is determined by an appraisal, the level of maturity reflects the extent of CMMI implementation in the organization [41]. The appraisal is essential to improve the process of organization, it helps understanding the maturity of the processes and prioritization of improvement among them. Most of the organizations are interesting and focusing on implementing the level two or level three of the CMMI maturity levels[41].

In this research, we are going to use the staged representation and focusing on level 2, which is managed level. At level 2, there are seven process areas that belong to different categories: Requirements Management which belong to Engineering category, configuration management, Measurement and Analysis and Pro-

cess and Product Quality Assurance are belonging to Support category, and the last category is Project Management which consists of Project Planning, Project Monitoring & Control, and Supplier Agreement Management. The focus at level two is on managing the project in an effective manner by planning, managing and controlling the project. At Figure 2.3, the five maturity levels and their focus is identified.

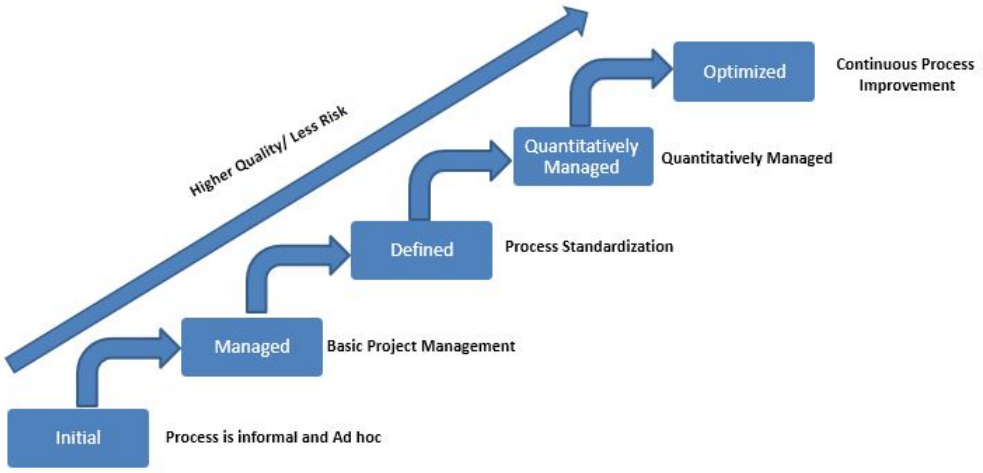

Figure 2.3: Maturity Levels

2.4.4 Project Monitoring and Control (PMC)

The project plan usually is to go through a lot of modifications, since it is rarely the case, during the project execution, that events occur as predicted by the plan. Based on the literature about project management [2, 42], the investigation especially about monitoring and controlling the software project in progress still is required [43]. The process areas project planning and PMC are the two of the main process areas in CMMI [29, 44]. The main purpose of PMC is managing the

activities of the project, keeping it on the track, and understanding the progress of the project. Corrective actions can be taken if the project deviates from the planned track. The PMC can be seen as the heart of the project management. In this process area, there are two specific goals which contain ten specific practices.

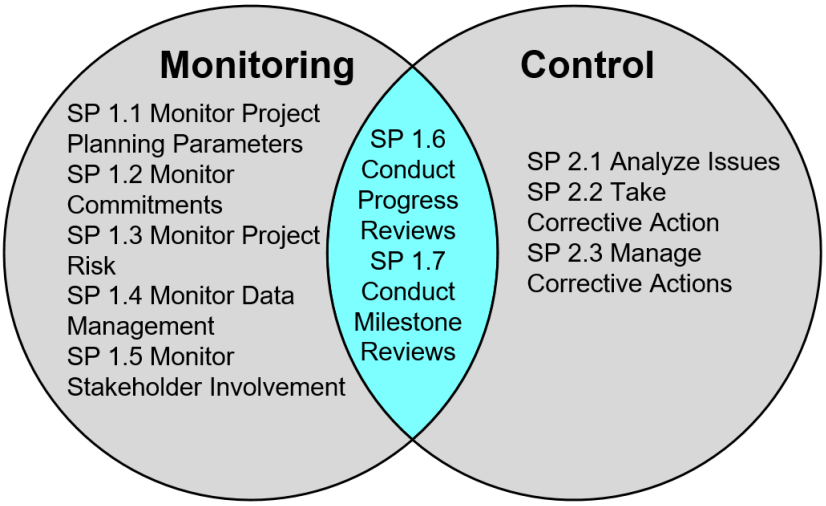

Figure 2.4: The specific practices of project monitoring and control(PMC)

Below, we explained these practices based on the formal specification of CMMI [5] as follow:

SG 1 Monitor the Project against the Plan: monitoring the progress and performance of the project against the plan of the project. The goal is strongly related with the planning process area to ensure that the project is executing according to predefined plan which means tracking and monitoring the elements that are planned in the planning process area. In order to achieve this goal, seven practices should be implemented.

SP 1.1 Monitor Project Planning Parameters: this is the first practice that concerns about monitoring the main elements of the project,

which are planning parameters. Planning parameters are schedule, cost, attributes of work products and tasks, resources and the skills, and knowledge of project staff. Those elements should be monitored periodically by comparing the actual one to the project plan, and identifying the deviation from the plan

SP 1.2 Monitor Commitments: the commitments either internal or external will be reviewed against the plan to ensure that they are satisfied and documented the result of the review.

SP 1.3 Monitor Project Risks: in this practice, the main activity is checking the status of the risks that are identified in project planning process area. Also, contact that new review with the relevant stakeholders.

SP 1.4 Monitor Data Management: monitoring the management of project's data against the project plan. The activities of data management should be reviewed periodically and document the main issues and re-plan the data management if it is necessary.

SP 1.5 Monitor Stakeholder Involvement: the aim of the practice is monitoring the planned involvement of stakeholders and re-planning the stakeholder involvement plan if is it necessary.

SP 1.6 Conduct Progress Reviews: this practice aims to review the progress of the project, performance and issues. The stakeholders identify the status of the project that is performed so far, reviewing the

result of collected measures and identifying the deviation of the plan for further change requests.

SP 1.7 Conduct Milestone Reviews: in this practice, the objective is reviewing the accomplishment of selected major events in the project. Clearly, there are interaction between progress review and milestone review.

SG 2 Manage Corrective Action to Closure: the second specific goal of PMC process area is managing the corrective actions to closure when the project deviate from the plan.

SP 1.1 Analyse Issues: collecting the issues from reviews and analyzing them to determine the need of corrective actions.

SP 1.2 Take Corrective Action: after identifying the issues, the next step is determining the appropriate action to be taken after getting the agreement with relevant stakeholders.

SP 1.3 Manage Corrective Actions: managing the corrective actions to closure by monitoring them and analyzing the effect of them on the project.

2.4.5 Conduct Progress Review

In order to monitor and control the project, we need to conduct the progress review periodically to identify as early as possible any difficulties and problems that might arise. The progress review is the evaluation of a life cycle work product(s) or status

of the project as viewed at a specific time when the project activities performed so far and their results and impacts are reviewed with relevant stakeholders [45]. Having the status reporting process will help the stakeholders or team members know whether tasks are on schedule or late. A project whose status is unknown has no realistic chance of being completed on time or on budget [46].

The main objective of this specific practice is to determine whether there are significant issues or performance shortfalls from the plan to be addressed and recommended for improvements. In order to have a good decision, the stakeholder should have a clear vision of the project and how to proceed. The expected outcome of this SP is detailed information about the project's progress that contains the results of the review. For each specific practice, there are some subpractices that facilitate the implementation of a specific practice. The following is a brief description of these subpractices:

Sub-practice 1:
Regularly communicate status on assigned activities and work products to relevant stakeholders. Managers, staff, customers, end users, suppliers, and other relevant stakeholders are included in reviews as appropriate.
Sub-practice 2:
Review the results of collecting and analyzing measures for controlling the project. The measurements reviewed can include measures of customer satisfaction.
Sub-practice 3:
Identify and document significant issues and deviations from the plan.
Sub-practice 4:
Document change requests and problems identified in work products and processes.
Sub-practice 5:
Document the results of reviews.
Sub-practice 6:
Track change requests and problem reports to closure.

Figure 2.5: The subpractices of SP 1.6: conduct progress review

The above subpractices can be categorized into three sections:

- Subpractices related to the project planning process area: subpractice 1.

- Subpractices related to the measurement analysis process area: subpractice 2.

- Subpractices related to the configuration management process area: subpractices 3, 4, 5, and 6.

In order to implement the progress review practice, the software development organization needs to interact with the three process areas, as in Figure 2.6.

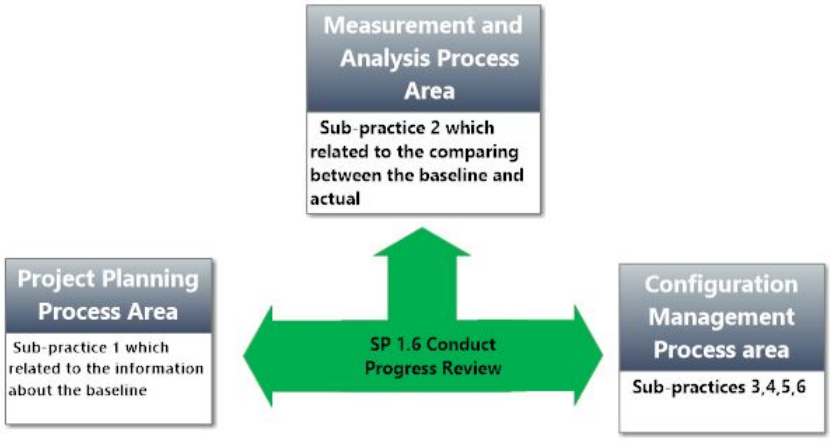

Figure 2.6: Subpractice categories of the conduct progress review specific practice

The relationships between the project planning and the project monitoring and control and the measurement and analysis process areas: The relationships between the three process areas have been discussed in [47], and the proposed context model is shown in Figure 2.7.

In this process area, the plan should be designed, and project estimates are made and revised as the project progresses. For instance, when the project is delayed, the plan should be revised to hire more people, extend the schedule, or

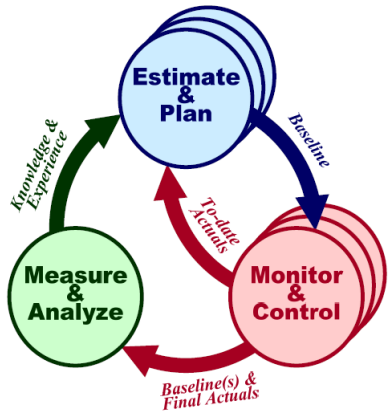

Figure 2.7: The interactions between software project management process areas both [1].

2.4.6 Conduct Milestone Review

Reviewing the project could be based on milestone completion. Lack of documented milestone deliverables and due dates is considered one of the main early warning signs of IT project failure [46]. Another way of reviewing the project's performance is based on the milestone deliverable. Having a documented milestone will facilitate meeting the objectives of the project. The team working on the project should have a clear plan about the short-term tasks that should be accomplished to get to the long-term objectives. Meeting the milestone deliverable means the plan of the project is executed as scheduled. Sometimes, later tasks depend on the completion of earlier ones. Completing a project on time requires all project team members to have a consistent understanding of the intermediate milestones, deliverables, and due dates that must be met to meet the overall objectives.

The expected outcome of this SP is detailed information results about the milestone of the project. For each specific practice, there are some subpractices that facilitate its implementation. The following are brief descriptions of these subpractices:

Sub-practice 1:
Conduct milestone reviews with relevant stakeholders at meaningful points in the project's schedule, such as the completion of selected phases. Managers, staff, customers, end users, suppliers, and other relevant stakeholders are included in milestone reviews as appropriate.

Sub-practice 2:
Review commitments, the plan, status, and risks of the project.

Sub-practice 3:
Identify and document significant issues and their impacts.

Sub-practice 4:
Document results of the review, action items, and decisions.

Sub-practice 5:
Track action items to closure.

Figure 2.8: Subpractice categories of the conduct milestone review specific practice

2.5 Characteristics and Challenges of Small and Medium-Sized Software Development Organizations

In this study, our focus will be mainly on SMEs that have a significant contribution to the development and growth of the economy [48]. SMEs help transform a developing country into a developed one [49]. In order to achieve sustainable economic growth, SMEs are promoted by many governments through some form of support and encouragement, such as facilitating loan procedures. The definition of SME is different from one country to another, and it is based on many variables, such as number of employees, assets, turnover or capital, and investments.

Country Name	Small	Medium	Study No
Saudi 1	25-59	60-99	[48]
Saudi 2	1-20	21-100	[48]
Malaysia	5-29	30-75	[50]
EU	10-49	50-249	[50]
Australia	5-19	20-199	[50]
Pakistan	10-35	36-99	[50]

Based on the literature, the most accepted element in differentiating between enterprises is the number of employees [50]. According to the Saudi Arabian General Investment Authority (SAGIA), a small enterprise is one that has between 25 and 59 employees, while a medium-sized enterprise is one that has fewer than 100 employees. Another definition from the Eastern Province Chamber of Commerce and Industry defines a small enterprise as having fewer than 20 and a medium-sized enterprise as having 20 to 100 employees, but we adopted the first definition because SAGIA is among the primary institutions responsible for managing the investment environment in the kingdom. Small software enterprises usually have a limited budget and less resources available for process improvement initiatives, so small enterprises implement a SCAMPI appraisal class B or C [41].

2.6 Literature Review

This section presents a review of key studies conducted on the thesis topic. The objective is to summarize and discuss the results of each study, which would allow a better understanding of the context of the problem.

2.6.1 Capability Maturity Model Integration

Almomani et al.[51] conducted a systematic literature review to investigate the SPI initiatives in SMEs. The study showed that most of the SPI initiatives in SMEs are conducted in America and Europe. In addition, the proposed SPI initiatives have some drawbacks, such as lack of generalizability, time consumption in implementing them, and the need for so much time for an SPI model to gain benefits. The reasons software development organizations do not adopt CMMI are identified in [20]. The results of this exploratory study show that small organizations do not adopt CMMI because of three main reasons: applicability of CMMI for small organizations, higher costs, and lack of time for SPI activities.

The motivations for adopting CMMI are identified based on 43 primary studies [52]. The main reasons an organization adopts CMMI are improvement of product quality and performance project. In addition, the result does not show the relationship between reasons for adoption and the size of the organization. Two questionnaires were made to identify the unofficial adoption of CMMI level 2 process area-specific practices by software SMEs based in Malaysia and Pakistan, and the result of this study shows that majority of software development SMEs

informally follow the specific practices of the CMMI level 2 process areas [50].

Galinac [53] proposed an SPI implementation strategy that has been developed and based on 14 best practices originating from CMMI's organizational process focus, which is adopted to suit large global software development (GSD) needs. This strategy is based on some different factors that lead to success and that consist of the selected best practices. Another framework is proposed to support the SPI in small organizations [21]. The framework is based on 13 process areas out of a continuous CMMI representation that suits the major business needs or goals of small software companies. The result shows that specific goals of project management are largely implemented.

The brief description of each paper is shown in the following table 2.6.2

2.6.2 Project Monitoring and Control & Small and Medium-Sized Enterprises

Wangenheim et al. [54] proposed a set of unified project management best practices by integrating high-level perspective PMBOK (4th ed.) processes and CMMI-DEV v1.2 specific practices of the basic project management process areas: project planning, project monitor and control, and supplier agreement management. The result showed an integration where the models complement each other and facilitate a simultaneous implementation and assessment of project management processes in conformance with both models. The researchers identified the dependencies between the seven process areas at maturity level 2 and the depen-

dencies between the specific practices at every process area [44]. The dependencies were extracted from the text of the CMMI specification. The result showed that project management and control (PMC) and project planning (PP) are key process areas at CMMI maturity level 2. In addition, the result plays an important role as a reference model for specific practices and process area dependencies for both SPI researchers and practitioners.

The process areas in level 2 were studied based on their perceived value associated with each specific CMMI practice. The data set consists of data from six software development companies ranging from small to medium size. Based on the perceived value of each practice, the CMMI practices were categorized as having high, medium, or low perceived value. Four out of the 10 specific practices of PMC is high, four is medium, and two is low [30].The earned value analysis (EVA) method was investigated to help in project monitoring and process area control in the CMMI software project maturity model [55]. It provides an accurate cost and schedule based on quantitative metrics. Another related investigation with the same earned value approach on four case studies of medium-sized construction projects was conducted in Malacca [56]. Advanced research on the perceived value of these specific practices was conducted by categorizing the specific practices based on the outcome area and activity [57]. The classification of specific practices based on the perceived value in [30] was systematically reanalyzed, and the result showed that SMEs tend to focus on high-level project-related outcomes and on planning and doing work on product-related outcomes instead of being

process focused.

The most interesting work focused on project monitoring and controlling in order to define general measures by applying the goal question metrics (GQM) paradigm to the two specific goals and its 10 specific practices of the PMC process area. These measures help the organization evaluate and control software products and processes [58].

Based on the literature, most of the studies about the progress review of a software project are for large organizations and cannot be adopted by SMEs. This study aims to help SMEs adopt CMMI and implement the progress and milestone review practices.This research provides a comprehensive view on how to review the progress and milestone in small and medium software development organizations effectively. There is a real need for more observational studies that clarify the implementation of PMC specific practices in small and medium-sized organizations. There is no study available until now that explores the implementation of progress and milestone reviews in small and medium-sized organizations.

Author	Reference	Date	Objective
Almomani et al.	[51]	2014	SPI initiatives in SMEs have some drawbacks, such as lack of generalizability, time consumption in implementing them, and the need for so much time for an SPI model to gain benefits.
M. Staples et al.	[20]	2007	Exploratory study shows that small organizations do not adopt CMMI because of three main reasons: applicability of CMMI for small organizations, higher costs, and lack of time for SPI activities.
M.Staples and Niazi	[52]	2008	The main reasons an organization adopts CMMI are improvement of product quality and performance project. In addition, the result does not show the relationship between reasons for adoption and the size of the organization.
J. Iqbal et al.	[50]	2015	identify the unofficial adoption of CMMI level 2 process area-specific practices by software SMEs. The majority of software development SMEs informally follow the specific practices of the CMMI level 2 process areas.
Galinac	[53]	2009	proposed an SPI implementation strategy that has been developed and based on 14 best practices suit large global software development (GSD) needs
M. Slvashankar et al	[21]	2010	Another framework is proposed to support the SPI in small organizations .The framework is based on 13 process areas.

Table 2.1: The literature review regrading the CMMI

Author	Reference	Date	Objective
Wangenheim et al.	[54]	2010	proposed a set of unified project management best practices by integrating high-level perspective PMBOK (4th ed.) processes and CMMI-DEV v1.2 specific practices
X. Chen et al.	[44]	2008	The researchers identified the dependencies between the seven process areas at maturity level 2 and the dependencies between the specific practices at every process area.
F. G. Wilkie et al.	[30]	2005	Based on the perceived value of each practice, the CMMI practices were categorized.
Z. Kedi and Y. Hongping	[55]	2010	The earned value analysis (EVA) method was investigated to help in project monitoring and process area control in the CMMI
M. Sauian and T. Mahmood	[56]	2009	Another related investigation with the same earned value approach on four case studies of medium-sized construction projects was conducted in Malacca
X. Chen and M. Staples	[57]	2007	The research is conducted by categorizing the specific practices based on the outcome area and activity
M. Khraiwesh	[58]	2013	project monitoring and controlling in order to define general measures by applying the goal question metrics (GQM) paradigm.

Table 2.2: The literature review regrading the PMC

CHAPTER 3

RESEARCH METHODOLOGY

In order to build the models of SP 1.6 and SP 1.7, we have identified their success criteria as in [36, 59]. The criteria is based on the best-known definition of usability in ISO 9241-11: "usability is the degree to which a software can be used by specified users to achieve specified objectives with effectiveness, efficiency, and satisfaction in a specified context of use". These criteria guided development and are later used to help evaluate the proposed models. The following criteria were used:

- User satisfaction: stakeholders should be satisfied with the results of the proposed models, and they should be able to use the proposed models to achieve specified objectives according to their needs and expectations.

- Easiness of models: the structure of the proposed models need to be easy in use and learn, since complicated models and standards are rarely adopted by organisations especially small and medium organizations as they require resources, training and effort.

After that, we have formulated the research questions that we should follow in our research based on the previous criteria of the expected models. The research questions have been mentioned in chapter 1 to form the scope of our investigation.

To answer the research question, we considered two ways of collecting information based on two phases. The first one was based on the extensive literature review by selecting papers that were most relevant to our objectives. A literature search methodology is used to take advantage of existing research. This existing research does not specifically have to be focused on the CMMI at specific practice level. The second phase was based on interviewing that focused on the qualitative aspect of the data collected using three practical models of the organizations.

An extensive literature review is based on analyzing research articles, published experience reports, and case studies. In addition, we analyze some of the specifications and recommendations to implement SPI in organizations. We limit our research to the material that is related to the progress or milestone review and gather the weaknesses and strengths of the existing models. We mainly use snowballing to find relevant literature—either backward snowballing, which is based on the list of references, or forward snowballing by finding citations to the papers [60, 61]. We used snowballing from the list of references of the identified articles via the articles identified through manual search using Google Scholar. A manual search through Google Scholar using terms such as: "CMMI", "SPI", "project monitoring and control", "progress review", "milestone review", "Small and medium-sized" were used to find starting sets. We are trying to minimize

bias in the research by covering the main sources and databases, which are ACM Digital Library, ScienceDirect, IEEEXplore, SprinerLink and John Wiley On-line Library. We The collected papers are reviewed to ensure that they are related to the progress or milestone review of the process management. As we can see, we do not follow the systematic literature review in our literature review as explained in [62].

Another method of collecting information about the progress and milestone review practices is interview. Interview is considered the most common format of data collection in qualitative research [63]. The interviews will be conducted with three representatives of three small and medium organizations. These two phases will give us confidence in the reliability of the data collected.

The collected data from these two phases will be analyzed by means of process called constant comparisons[64]. By using the the constant comparison, we are able to compare between different views of implementations. In order to combat the lack of existing focused research, a tailored version of techniques from the grounded theory research method, used often in sociology and psychology, is included in the methodology. The grounded theory approach uses existing data collected in studies on process of interest. The model is built based on the continued collection and analysis of data as in [64], an interrelationship between data collection and analysis is illustrated in Figure 3.1

The results compiled from the literature and interviewing will be interpreted and analyzed in alignment with research objectives in order to answer the research

Collect data Analyze data

Figure 3.1: Interrelationship between data collection and analysis

questions. After collecting and analysing data, we will try to build our models of progress review and milestone review that meet the criteria.

Building the model means identifying the path that is appropriate for SME software development organizations to follow. The last step is the model evaluation, which will be performed through an expert panel review process. The experts should have an experience in SPI models in order to evaluate the effectiveness of the proposed model and make any refinements for that model if necessary [29]. The reviewers should have knowledge about the CMMI, and they were asked to rank their knowledge in scale from 1 to 5. We only consider the evaluation of expert if they have at least 5 years of experience in SPI, and their knowledge of CMMI is 3 and above. In order to capture their evaluation, the reviewers are asked to fill out the questionnaire. In Figure 3.2 the main steps of the research methodology are shown.

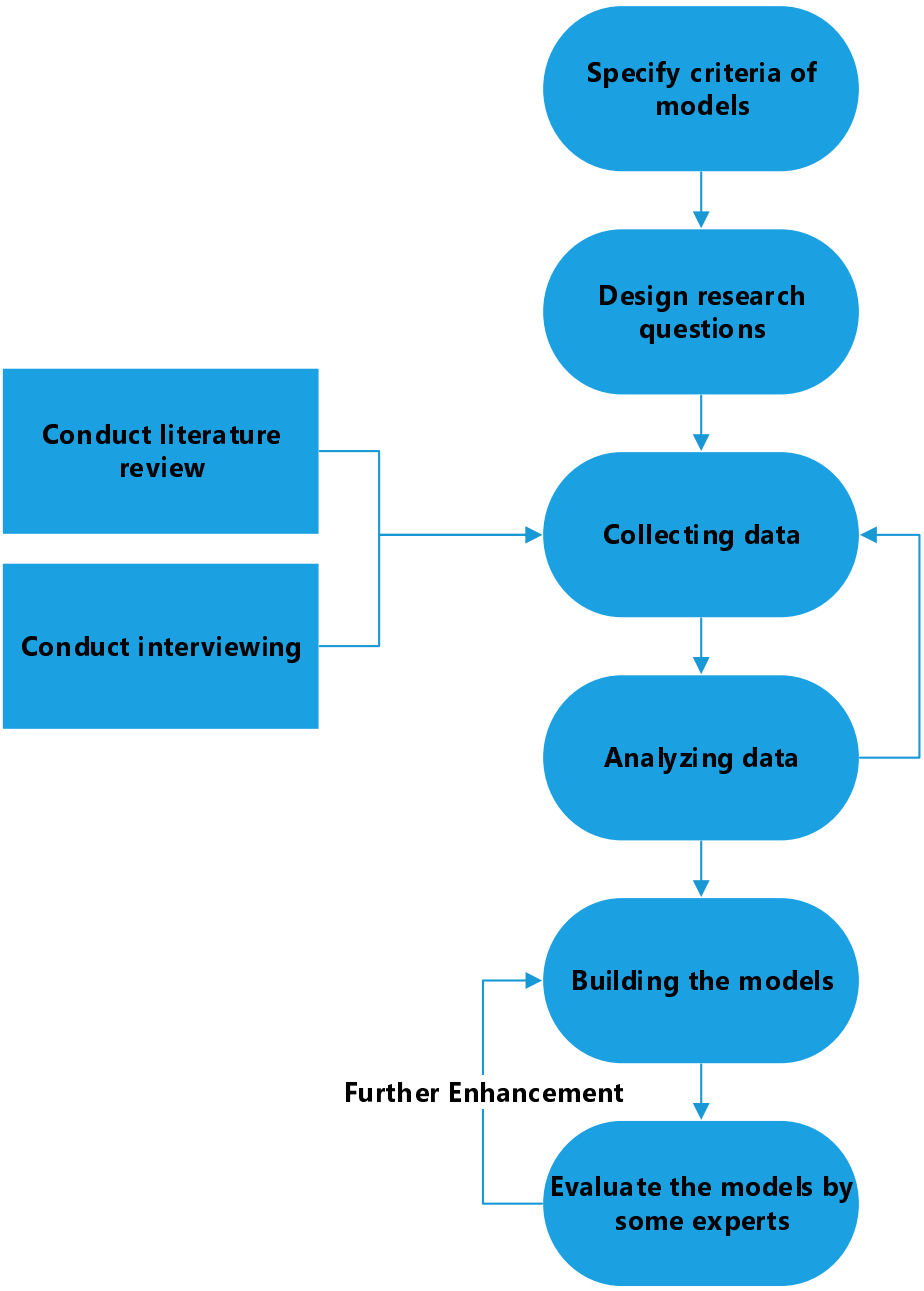

Figure 3.2: Steps of the research methodology

CHAPTER 4

RESULTS

In this chapter we present the results and analysis from following our research methodology. Also, we are going to describe the models that are identified from the literature and the interview in the following sections.

4.1 Models Based on the Literature

In this section, we have surveyed the literature in order to identify the suitable models to implement the progress and milestone review practice. In addition, we believe that these models are capable of implementing the conduct progress review specific practice at CMMI level 2. These models will be briefly reviewed in the following subsections.

4.1.1 Progress Review Process in [1]

One of the models that has been highlighted in the literature [1] is the project control model, which consists of four elements:

- A measuring device that detects what is happening.
- A mechanism for comparing what is actually happening with some standards or expectations of what should be happening.
- A procedure for altering behavior if the need for doing so is indicated
- A means of transmitting feedback information to the control device

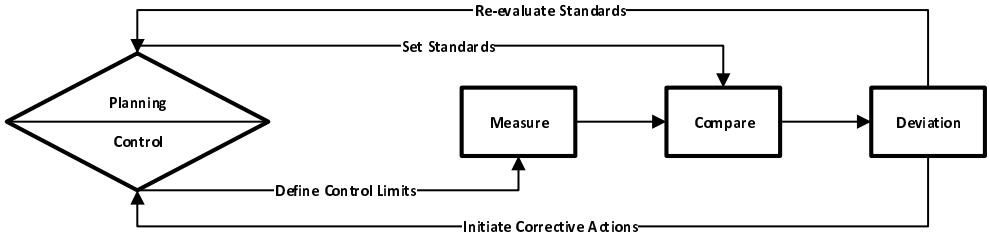

Figure 4.1: Progress Review Process in[1]

4.1.2 Progress Review Process in [2]

In [2], Hughes et al. draw a model that describes the project control cycle. The first step of the model after publishing the project plan is to gather the required information about the project and the result of the monitoring. The next step is to compare between the actual achievement and the planned outcome. Based on the comparison, if the mismatch is unsatisfactory, the stakeholders will take remedial action by replanning or revising the target. On the other hand, if the mismatch is satisfactory, then no action is required. The next step is about completing the project. If the project is not completed, the process of the review will start again by collecting information. If the project is completed, the review

and documentation will be very useful in feeding the future planning stage of the project.

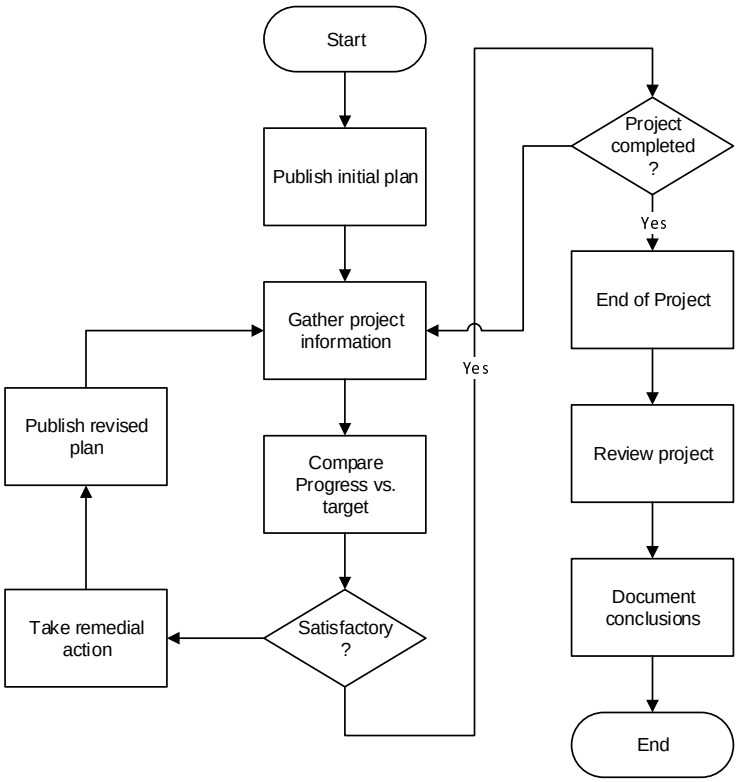

Figure 4.2: Progress review process in [2]

4.1.3 Progress Review Process in [3]

Based on[3], after some of the work is done, the review progress is required by checking the progress measurement to ensure that the required results are achieved. In case of any shortfalls, the recovery action is taken based on the variance. If it is small, do nothing. If it is big, either replan the work to recover the original plan or revise the plan to accept the current situation. The objective of checking the progress is to take action to overcome any deviation from the plan "control." The plan should be frozen into a baseline to provide a fixed measure

for control. An effective review usually gathers data and determines whether the project is behaving as predicted. If it is not, then calculate the size and impact of the variances. The most important quantitative measures are cost and time through a comparison of the actual achievement and the baseline. Gathering data on progress is crucial in defined criteria. Calculating progress on all five project management functions—time, cost, quality, project organization, and scope- to forecast the final outturn is part of forward-looking control.

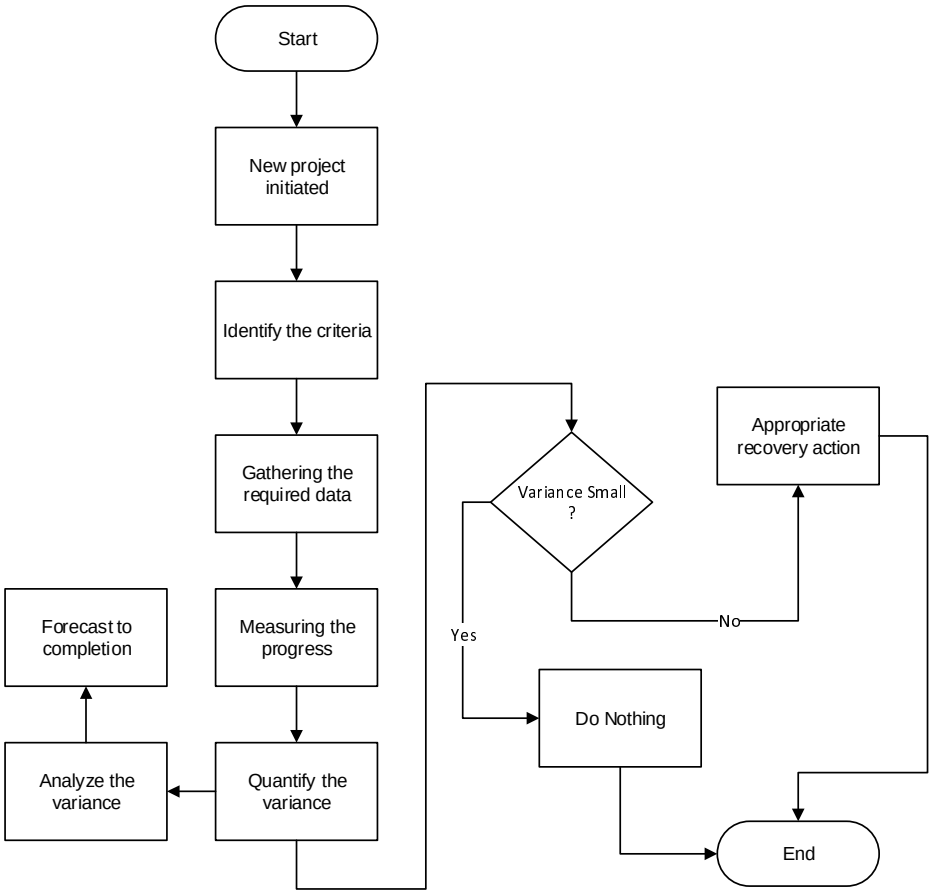

Figure 4.3: Progress review process in [3]

4.1.4 Progress Review Process in [4]

In [4], the model starts by collecting the result of monitoring to identify the change or technical variance. These variances bring about chaos to the planned parameters. The variance could occur in scope, time, risks, resources, and methods. After the variance is measured, the problem will be described and investigated by the project team in collaboration with external stakeholders. The result of the previous step is a solution report that will inform the stakeholders. The last step is to update the planned parameter. The detailed flow activity diagram is shown in Figure 4.4.

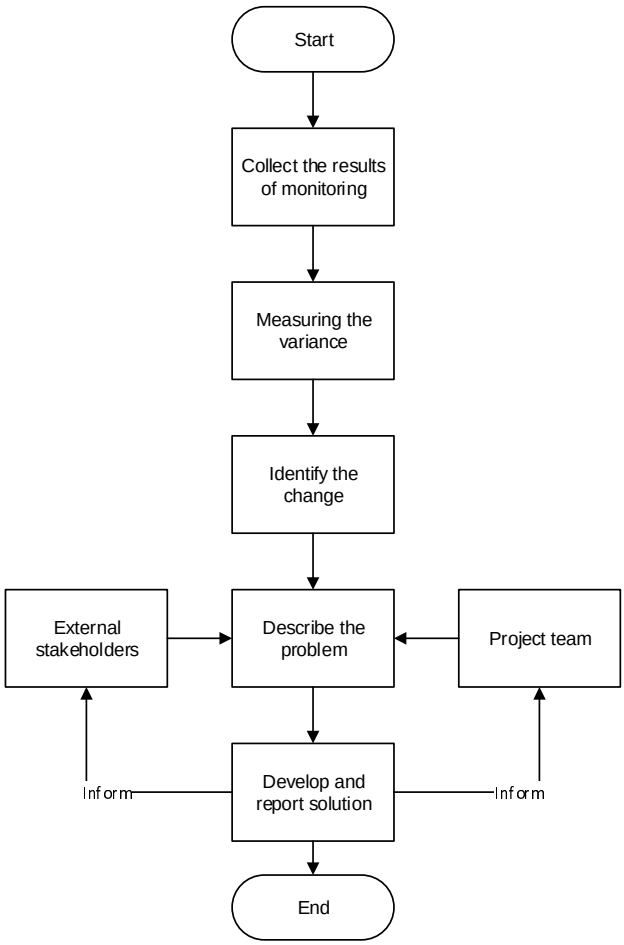

Figure 4.4: Progress review process in [4]

4.2 Models Based on Interview

In this section, we have asked two representatives of two small and medium-sized software development organizations to answer the following three questions:

- Who is the initiator of the progress and milestone review process request?
- How did your company use to review the progress of the project? (Please draw a process map)
- How did your company use to review the milestone of the project? (Please draw a process map.)

Regarding the first question, the respondents agreed that a project manger is the one who is responsible for initiating the progress and milestone review request. Usually this task is assigned to anyone outside the project team to avoid any bias in identifying issues during the review.

4.2.1 Company A's Progress Review Process

In this company, the model for reviewing the progress starts by identifying the baseline of the project. Once the baseline is clarified, the data of the actual progress will be collected. In next step, the planner will calculate the earned value by using the EVA. The result will be sent to the project manager to decide on the appropriate corrective action if the variance is negative. Otherwise, the progress review process will end. The detailed flow activity diagram is shown in Figure 4.5.

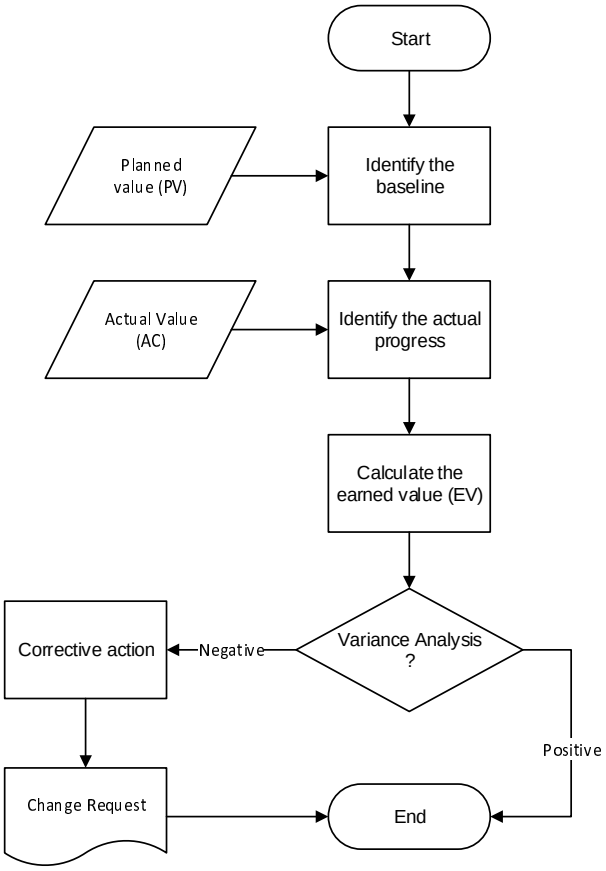

Figure 4.5: Progress review process for company A

4.2.2 Company B's Progress Review Process

In company B, the reviewing process of progress starts by imitating the process that affords some kind of security and is authorized to selected users. The next step is to revise the baseline of the project to collect data based on it. After the required data are gathered, the measurement step is implemented to make a comparison and update the estimate. In addition, the forecasting of the completion of the current project and future projects is maintained. The next stage is to investigate the significant deviations regarding the baseline and its causes. Before the corrective action is taken, the database of the more probable risks and appro-

priate actions is reviewed, and a new action is developed if necessary. Before the plan is updated, a discussion has to be held to make an agreement on the more feasible corrective action. The detailed flow activity diagram is shown in Figure 4.6.

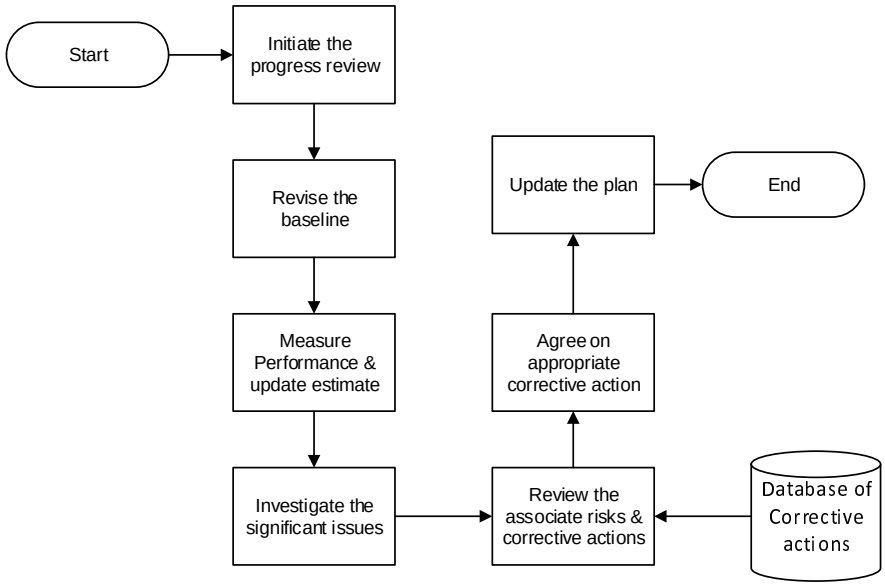

Figure 4.6: Progress review process for company B

4.2.3 Company C's Progress Review Process

In company C, the reviewing process of progress starts by project manger. The project manger receives a report about the current completion of the project from the the project team. After that, the comparison is done between the planned and actual progress. Once a variance is appeared, its impact on the project should be investigated, if the variance has significant impact a change request should be triggered, otherwise continue monitoring the schedule. The change request should be conceived and analyzed before its implemented, and it needs acceptance and

approval from project sponsor to ensure the availability of required resources. At the end the plan of the project should be updated.

The detailed flow activity diagram is shown in Figure 4.7.

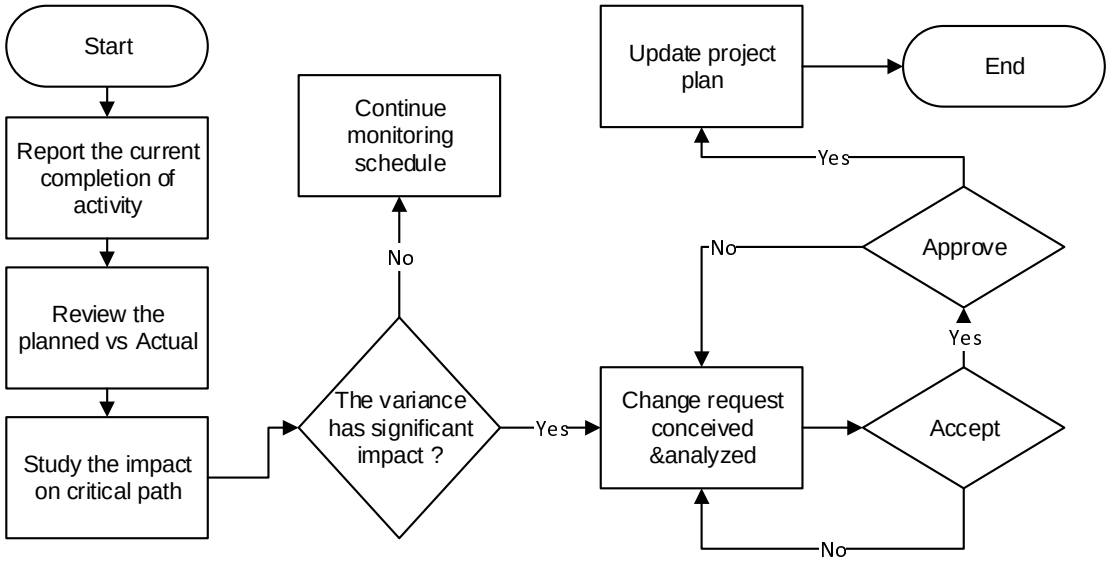

Figure 4.7: Progress review process for company C

4.3 Proposed Model

Based on the previous seven models, we proposed two models consist of six stages, that will lead small and medium-sized software development organizations to implement SP 1.6 and SP 1.7 since these organizations have limited resources. Based on the identified models, all models have four common activities: gathering the required information, measuring progress, comparing progress, and making a corrective action. The detailed flow activity diagram is shown in Figure 4.8.

First Stage: Initiating Initiating the process of review by filling a request for progress review by the project manager as in [4] and the model of company

B. The project manager is usually the one who is responsible for initiating the request.

Second Stage: Identifying the Criteria The second stage is related to the understanding of team members about the progress review request and the objective of the request to mitigate any misunderstanding [65]. This step can be skipped if the reviewer is one of the project team but it is recommended to choose the independent reviewer to mitigate the bias in reporting the issues. One of the main drivers of project management success is ensuring the understanding of expectations and delivering results [66]. Also, understanding the baseline of the project provides a fixed measure for the comparison stage [3]. In addition, we need to identify the criteria for collecting information as in [3, 67]. The criteria could be general, such as schedule, budget, or quality [68], since software project performance is typically defined in terms of three main factors: cost, duration, and quality [69, 70]. The criteria minimize effort in order to collect information about the project. In the measuring step, we should have specific measures that indicate the exact status of the progress. Specifying the measures will facilitate the gathering of information.

Third Stage: Gathering Information and Resources The third stage is gathering information and resources based on the specified criteria in the previous step. Gathering the required resources is the main step for reviewing progress. The seven models share this step, and this is recommended by

a CMMI formal specification [5]. This step could be the results of monitoring the project as in [4]. When the previous specific practices of PMC from one to five is implemented, the output will be the required information of monitoring.

Fourth Stage: Measuring Progress The fourth stage is measuring progress [3, 4] and making a comparison [2, 3] which is the main activity for identifying the deviation and significant issues [5]. The measurement analysis area has been deeply investigated in small and medium-sized software development organizations [67, 71]. A detailed description of the measures that can be used is shown in the table below:

Criteria	Measures
Quality	Potential defects, defect removal efficiency, delivered defects, defects per function point, defects per thousand lines of code, internal customer satisfaction
Schedule	Successful phase exits, time to market, milestone completion and predictability of delivery, work product completions
Budget	Product cost variance to plan, resource utilization

The EVA is one way of measuring the project's progress as in the model of company A. Specifying the measures should be aligned with the project objectives. Two of the main measures are customer satisfaction [5] and milestone completion [68]. After that, we need to compare the planned

against the actual progress to see whether there are any variances. Based on that, if there is no variance, we will document the progress review and finish the process; but if there is any variance, they need to be handled in the next stage. As recommended by CMMI formal specification, measuring the progress activity can be implemented effectively by implementing two specific goals of measurement and analysis process are to ensure making informed decisions and taking appropriate corrective action.

Fifth Stage: Identifying the Issues The fifth stage is identifying the issues or deviation based on the variance that appeared in the previous stage. This is one of main objectives of reviewing the performance or progress. Once the issues are identified, the issues need to be analyzed and their impacts before they seeking to change request. The project team should spend much effort and time to get a reasonably good understanding of the root causes and the environment of the project [72]. The issues will be analyzed and their impacts on the progress should be clear before we initiating the change request, if the issue does not affect the progress of the project, we do not need to initiate change request. The change request should be initiated when the issue has a significant impact on the progress, since the change request need much attention and resources, the discussion should be held before as a meeting, and change request is accepted by project manger. We can control and track change request effectively by implementing specif practice SP 2.1 Track Change Requests in configuration management process area.

Implementing CM.SP 2.1 Track Change Requests imply the following:

1. Initiate and record change requests in the change request database.
2. Analyze the impact of changes and fixes proposed in change requests.
3. Categorize and prioritize change requests.
4. Review change requests to be addressed in the next baseline with relevant stakeholders and get their agreement.
5. Track the status of change requests to closure.

Batching the change request suggests that the proposed change will occur after some specified period (future implementation).

Sixth Stage: Documenting, Updating, and Communicating The last stage is making sure that the change request is solving the problem by checking the status of the request. If the problem is not solved, the request will return to discuss and initiate a change request; the updating activity for each status of the change request, plan, and estimate of the project is updated as in [2] and model B. After that, the progress review results will be documented [5]. The last activity is communicating the document of the progress review with the stakeholders to obtain their approval before proceeding further as in [4, 67].

4.3.1 Conduct Milestone Review Model

Based on the literature, the milestone are pre-planned events or points in time or schedule at which a thorough review of status is conducted to understand how well stakeholder requirements are being met. The milestones are planned during project planning to ensure what deliverables should be delivered at every milestone. Since CMMI formal specification mentioned that "A single review can address the intent of both." For example, a single pre-planned review can evaluate progress, issues, and performance up through a planned time period (or milestone) against the plan's expectations. The proposed model for SP 1.7 "conduct milestone review" is same as SP 1.6 except that the criteria that helps to gather information is not needed, since the milestone completion regarding the schedule is our main measure. The detailed flow activity diagram is shown in Figure 4.9.

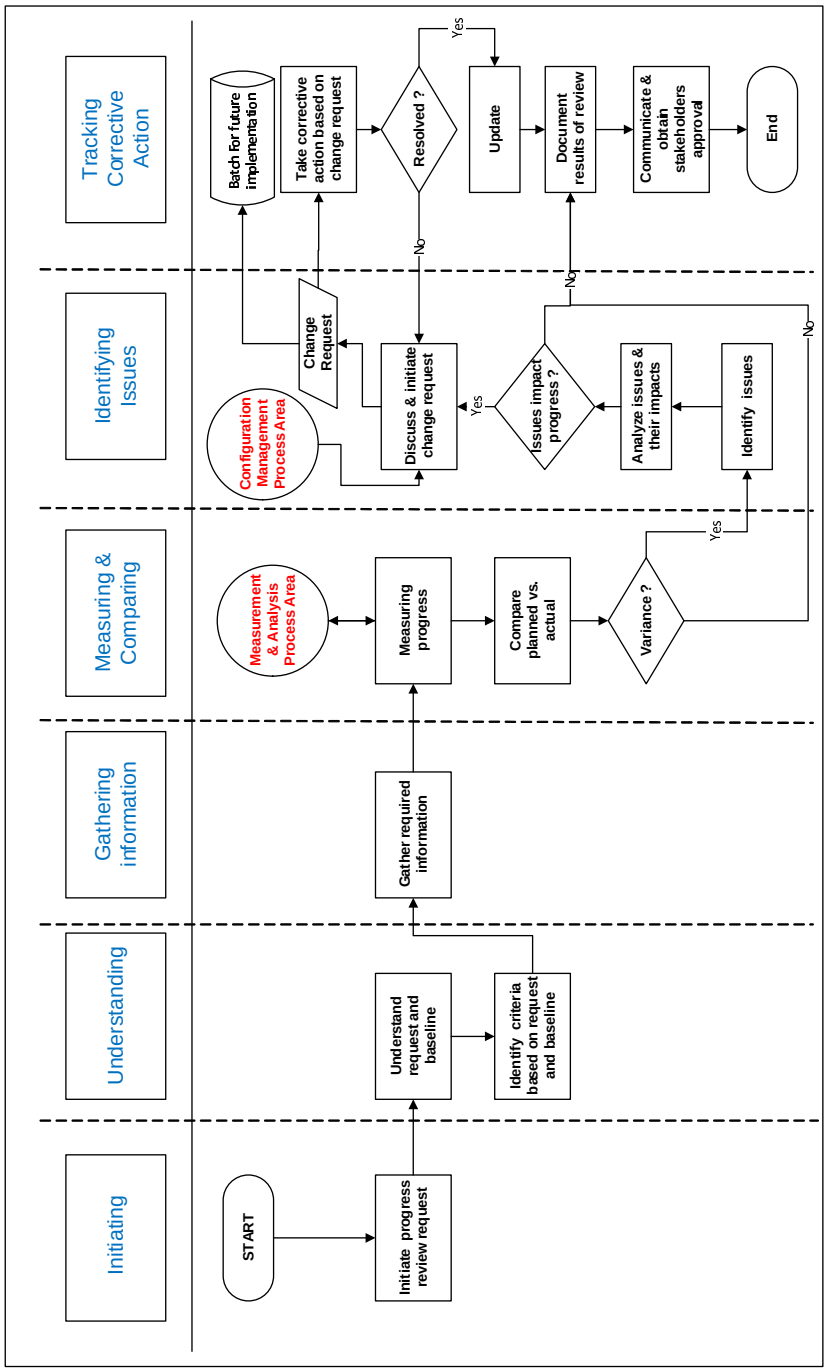

Figure 4.8: Proposed model of conduct progress review practice

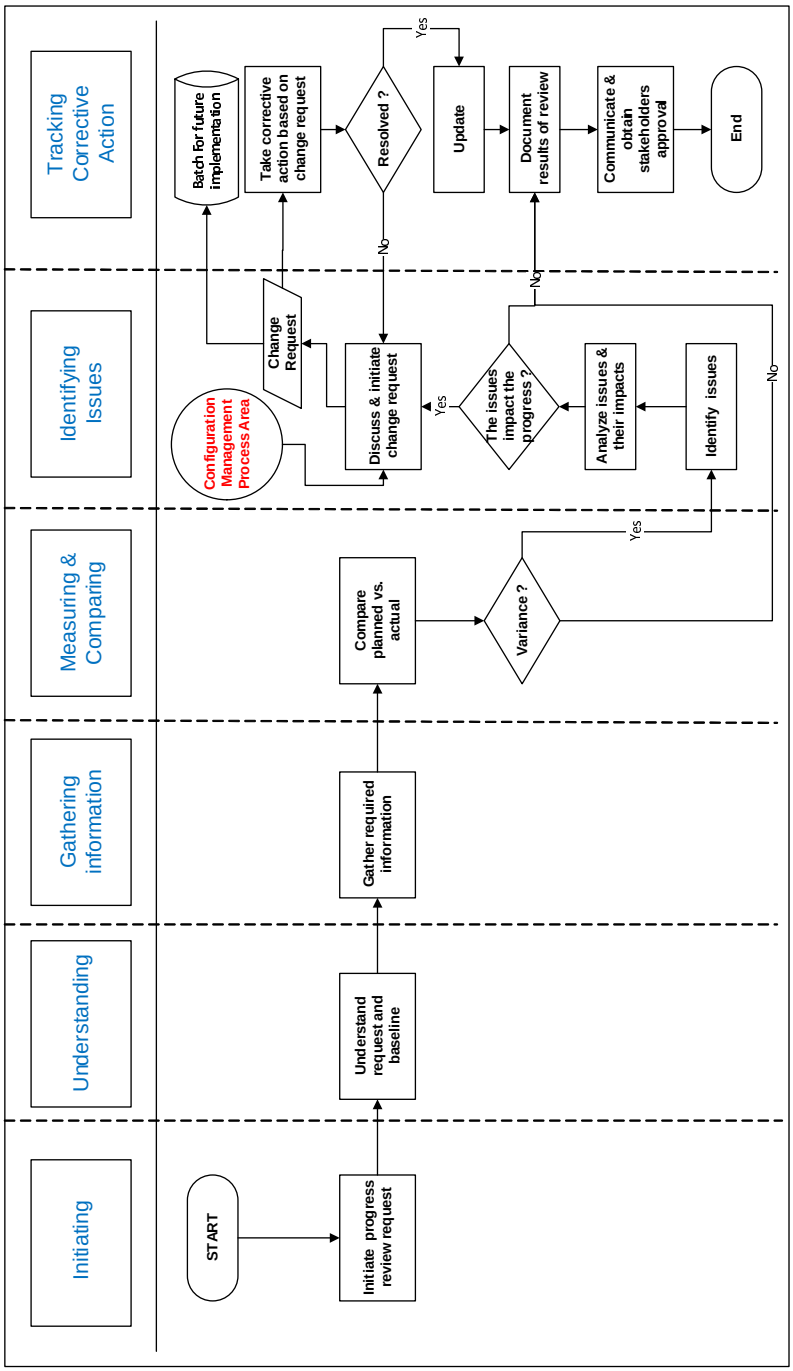

Figure 4.9: Proposed model of conduct milestone review practice

CHAPTER 5

MODEL EVALUATION

5.1 Evaluation of the proposed models through an expert panel review process

The proposed model is evaluated through an expert review process. The initial evaluation is performed in order to get the experts' opinions about the models. We contacted five SPI experts who have experience in software development and SPI-related activities.The SPI reviewers involved in the evaluation were selected based on their experience in the field of software process improvement. They were asked to rank their knowledge in scale from 1 as "Low" to 5 as "High". We consider their evaluation if they have experience more than five years and their knowledge about CMMI is more than three. The experts' profiles are presented in table 5.1 below:

In order to seek SPI experts' opinion about the models, a questionnaire was developed. We adopted some questions from [24] to meet the objective of the

SPI expert	Job title	Experience of SPI expert in years	Knowledge of CMMI(Low 1 - 5 High)	Company size
1	Project manger	11	4	Medium
2	Project manger	7	3	small
3	Project consultant	7	4	Medium
4	Software Developer	8	4	Small
5	Software Developer	10	3	Small

Table 5.1: SPI experts' profile

research. In addition, the questions were designed in a way that could capture the required information and feelings about the model. Recording the responses is the best option to minimize the bias of missing any key points and the best choice to make the evaluation more effective [63]. Before the experts submitted their evaluation, I asked them to respond to the following:

- What is the current position ?
- How many years of industry experience do you have in Software Process Improvement projects?
- Please rank your knowledge about Capability Maturity Model Integration (CMMI) by circling a response on the following scale: using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all"
- Specify the size of your organization.
- Specify the number of employees in your organization.

The questionnaire consists of four sections as following:

1. In this section, it contains title, key terms, description of project, survey procedure, data repository, privacy of collected data, right to withdraw from participation, contact details and agreement participate in this research survey.

2. In this section, project monitoring and control process area is elaborated along with the description of the SP 1.6 conduct progress review and SP 1.7 conduct milestone review.

3. In this section, we describe every stage of proposed model of SP 1.6 conduct progress review and the its associated questions.

4. In this section, we describe every stage of proposed model of SP 1.7 conduct milestone review and the its associated questions.

Summary of evaluation results for SP 1.6 is presented and shown in Table 5.2. Regarding the first question of the questionnaire which is related to the model's satisfaction to the objective of specific practice. Based on a scale range from five as "strongly agree" to one as "strongly disagree" one expert chose " Strongly agree " and four out of five experts chose " agree " for the proposed model SP 1.6. This indicates that all of the experts agreed about the proposed model satisfies the goal of the specific practice SP 1.6, according to CMMI formal specifications.

The next two questions are related to the research question **What is the perceived "ease of learning and ease of use" of the proposed model?**. In the first question, the experts were asked about clarity of the proposed model's

representation, using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all", two experts chose "5", one chose "4", one chose "3", and one chose "2". Due to the diversity of responses, we chose the majority where three experts either selected "five" or "four". The other question is about a knowledge of CMMI that is required to learn how to use our proposed model for SP 1.6, using a scale of 1 to 5, with 5 as "too much knowledge" and 1 as "not at all", one chose "1" two experts chose "2", two experts chose "3". Therefore, we conclude that the SPI expert reviewers had positive impressions about proposed model regarding the ease of both learning and using.

In addition, four questions were formulated related to research question **What is the perceived "usefulness" of the proposed model?**. In the first question, the experts were asked about the usefulness of the model in the software industry. using a scale of 1 to 5, with 5 as "very" and 1 as "not at all", three experts chose "5", one chose "4", and one chose "3". The second and third questions are related to model's ability to improve the software process and lead to the production of high-quality software products and mange the progress review during the project. Two experts chose "Strongly agree", and three chose "Agree". The fourth question about maintaining customer satisfaction in targeting their needs. Two experts chose "Strongly agree", two chose "Agree", and one chose "Neutral". In general, the received responses indicate that the proposed model is useful and capable to satisfy the needs of the stakeholders.

The last question of questionnaire is related to research question **What is**

the "perceived applicability" of the proposed model?. One expert chose "Strongly agree", and four chose "Agree". Overall, the results of the expert evaluation showed that our proposed model is applicable to small and medium-sized software development organizations.

Question	**No. of Experts**	**Strongly agree OR (5)**	**Agree OR (4)**	**Neutral OR (3)**	**disagree OR (2)**	**Strongly disagree OR (1)**
The proposed model for SP 1.6 satisfied the goal of the specific practice, according to CMMI v1.3 specifications which is "Periodically review the project's progress, performance, and issues"	5	20%	80%			
How clear is the representation of our proposed model for SP 1.6 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all"	5	40%	20%	20%	20%	

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Table 5.2 – *Continued from previous page*

Question	**No. of Experts**	**Strongly agree OR (5)**	**Agree OR (4)**	**Neutral OR (3)**	**disagree OR (2)**	**Strongly disagree OR (1)**
How much knowledge of CMMI is required to learn how to use our proposed model for SP 1.6 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all"	5			40%	40%	20%
How useful would it be to the software industry to use our proposed model for SP 1.6 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all"	5	60%	20%	20%		
The use of our proposed model for SP 1.6 would improve the software process and lead to the production of high-quality software products.	5	40%	60%			

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Table 5.2 – *Continued from previous page*

Question	**No. of Experts**	**Strongly agree OR (5)**	**Agree OR (4)**	**Neutral OR (3)**	**disagree OR (2)**	**Strongly disagree OR (1)**
The use of our proposed model for SP 1.6 would help mange the progress review during the project	5	40%	60%			
The use of our proposed model for SP 1.6 would maintain customer satisfaction in targeting their needs.	5	40%	40%	20%		
Our proposed model for SP.1.6 is applicable to small and medium software development organization. In other words, it can be applied to both small and medium software development organization.	5	20%	80%			

Table 5.2: Evaluation response of proposed model for SP 1.6 “conduct progress review”

Summary of evaluation results for SP 1.7 is presented and shown in Table 5.3.

Regarding the first question of the questionnaire which is related to the model's satisfaction to the objective of specific practice. Based on a scale range from five as "strongly agree" to one as "strongly disagree" one expert chose " Strongly agree " and four out of five experts chose " agree " for the proposed model SP 1.7. This indicates that all of the experts agreed about the proposed model satisfies the goal of the specific practice SP 1.7, according to CMMI formal specifications.

The next two questions are related to the research question **What is the perceived "ease of learning and ease of use" of the proposed model?**. In the first question, the experts were asked about clarity of the proposed model's representation, using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all", one expert chose "5", two chose "4", one chose "3", and one chose "2". Due to the diversity of responses, we chose the majority where three experts either selected "five" or "four". The other question is about a knowledge of CMMI that is required to learn how to use our proposed model for SP 1.7, using a scale of 1 to 5, with 5 as "too much knowledge" and 1 as "not at all", one chose "1" two experts chose "2", two experts chose "3". Therefore, we conclude that the SPI expert reviewers had positive impressions about proposed model regarding the ease of both learning and using.

In addition, four questions were formulated related to research question **What is the perceived "usefulness" of the proposed model?**. In the first question, the experts were asked about the usefulness of the model in the software industry. using a scale of 1 to 5, with 5 as "very" and 1 as "not at all", one expert chose "5",

three chose "4", and one chose "3". The second questions are related to model's ability to improve the software process and lead to the production of high-quality software products, one expert chose "5", three chose "4", and one chose "3". In third question, the experts were asked about the ability of proposed model to mange the milestone review during the project, one expert chose "Strongly agree", and four chose "Agree". The fourth question about maintaining customer satisfaction in targeting their needs. One expert chose "Strongly agree", four chose "Agree". In general, the received responses indicate that the proposed model is useful and capable to satisfy the needs of the stakeholders.

The last question of questionnaire is related to research question **What is the "perceived applicability" of the proposed model?**. One expert chose "Strongly agree", and four chose "Agree". Overall, the results of the expert evaluation showed that our proposed model is applicable to small and medium-sized software development organizations.

Question	**No. of Experts**	**Strongly agree OR (5)**	**Agree OR (4)**	**Neutral OR (3)**	**disagree OR (2)**	**Strongly disagree OR (1)**
The proposed model for SP 1.7 satisfied the goal of the specific practice, according to CMMI v1.3 specifications which is "Review the project's accomplishments and results at selected project milestones"	5	20%	80%			
How clear is the representation of our proposed model for SP 1.7 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all"	5	20%	40%	20%	20%	
How much knowledge of CMMI is required to learn how to use our proposed model for SP 1.7 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all"	5			40%	40%	20%

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Table 5.3 – *Continued from previous page*

Question	**No. of Experts**	**Strongly agree OR (5)**	**Agree OR (4)**	**Neutral OR (3)**	**disagree OR (2)**	**Strongly disagree OR (1)**
How useful would it be to the software industry to use our proposed model for SP 1.7 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all"	5	20%	60%	20%		
The use of our proposed model for SP 1.7 would improve the software process and lead to the production of high-quality software products.	5	20%	60%	20%		
The use of our proposed model for SP 1.7 would help mange the milestone review during the project	5	20%	80%			
The use of our proposed model for SP 1.7 would maintain customer satisfaction in targeting their needs.	5	20%	80%			

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Table 5.3 – *Continued from previous page*

Question	**No. of Experts**	**Strongly agree OR (5)**	**Agree OR (4)**	**Neutral OR (3)**	**disagree OR (2)**	**Strongly disagree OR (1)**
Our proposed model for SP.1.7 is applicable to small and medium software development organization. In other words, it can be applied to both small and medium software development organization.	5	20%	80%			

Table 5.3: Evaluation response of proposed model for SP 1.7 "conduct milestone review"

Finally, according to the initial evaluation, we are assured that our proposed models are easy to use and learn. Moreover, the proposed models can assist small- and medium-sized software development organizations in implementing SP 1.6 and SP 1.7 of the PMC process area, as stated by CMMI formal specifications.

5.2 The novelty of the proposed models

In this section, we compared the proposed model with other six models in terms of meeting the objectives of SP 1.6 and SP 1.7, specific criteria, and activities of the models.

5.2.1 Comparison Between Proposed Models with Existing Models Based on Specific Criteria

In table 5.7, the main differences that exist between the proposed model and with the existing models in literature and interview are describes based on the specific criteria.

5.2.2 Comparison Between Proposed Models with Existing Models Based on the Activities

This thesis focuses on the development of the software progress and milestone review models. The purpose of the research is to overcome the shortcomings found in the existing models through the proposed progress and milestone review models. It was found during the literature review and interview that the existing models missed some of the important activities. The similarities and the differences of the proposed model with the existing models are based on the activities as shown in Table 5.5.

The comparison is based on the following scope[73].

Criteria	Reference							Proposed model
	[1]	[2]	[3]	[4]	A	B	C	
A model that is staged or phased		✓	✓		✓	✓	✓	✓
Developing the model according to the objectives of SP 1.6 and SP 1.7 stated in the CMMI specifications								✓
Addressing the PMC process area at specific practice level								✓
For small- and medium-sized organizations in particular								✓
The development of the model based on specific criteria(i.e., ease of use, stakeholders' satisfaction)								✓
The initial evaluation of the model regarding "practice satisfaction,""ease of learning and ease of use,""user satisfaction," and "applicability to small- and medium-sized software development organizations" performed								✓
Templates and guidelines ar presented								✓

Table 5.4: The main differences that exist between the proposed model and the earlier models found in the literature

Activity	Reference							Proposed model
	[1]	[2]	[3]	[4]	A	B	C	
Initiating the request						✓		✓
Understand the request and baseline	✓				✓	✓		✓
Identify the criteria			✓					✓
Gathering the required resources		✓	✓	✓			✓	✓
Measuring the progress	✓		✓	✓	✓	✓		✓
Comparing the planned vs the progress	✓	✓			✓		✓	✓
Identify the issues				✓		✓	✓	✓
Discuss and initiate	✓			✓				✓
Change request					✓		✓	✓
Corrective action based on the request		✓	✓		✓			✓
Update	✓	✓				✓	✓	✓
Document the results		✓						✓
Communicate				✓				✓

Table 5.5: Comparison of the proposed model with the existing models in literature and interview

- Which activities are missing in the existing models?
- Which missing activities are covered by the proposed model?

5.2.3 Comparison Between Proposed Model SP 1.6 with Existing Models Based Meeting Subpractices

In this subsection, we have compared between the models in terms of meeting the required subpractices which mentioned in CMMI formal specification. The formal defin subpractice is a detailed description that provides guidance for interpreting and implementing a specific practice.

Subpractice no.	Reference							Proposed model
	[1]	[2]	[3]	[4]	A	B	C	
Regularly communicate status on assigned activities and work products to relevant stakeholders.				✓			✓	✓
Review the results of collecting and analyzing measures for controlling the project.	✓	✓	✓	✓	✓	✓	✓	✓
Identify and document significant issues and deviations from the plan.				✓		✓		✓
Document change requests and problems identified in work products and processes.					✓		✓	✓
Document the results of reviews.		✓						✓
Track change requests and problem reports to closure.							✓	✓

Table 5.6: Comparison of the proposed model of SP 1.6 with the existing models in literature and interview

Subpractice no.	Reference							Proposed model
	[1]	[2]	[3]	[4]	A	B	C	
Conduct milestone reviews with relevant stakeholders at meaningful points in the project's schedule, such as the completion of selected phases.							✓	✓
Review commitments, the plan, status, and risks of the project.	✓	✓	✓	✓	✓	✓	✓	✓
Identify and document significant issues and their impacts.				✓		✓		✓
Document results of the review, action items, and decisions.		✓					✓	✓
Track action items to closure.							✓	✓

Table 5.7: Comparison of the proposed model of SP 1.7 with the existing models in literature and interview

5.2.4 Comparison Between Proposed Model SP 1.7 with Existing Models Based Meeting Subpractices

CHAPTER 6

LIMITATIONS & CONCLUSION

6.1 Limitations

Some limitations of this work could be considered threats to validity. The results of this research are based on normal literature review in collecting data. We tried to cover the articles and high-level specification books, but a threat to validity could stem from the fact that we did not include all articles related to the review of progress, which could affect the completeness of the study search, to mitigate this snowballing was used to collect more data. External validity is the degree to which the result could be generalized. We could not generalize the results to all small and medium-sized software development organizations because of the bias that could have occurred during the stage of information collection and the model evaluators. a pilot study was conducted to ensure the questions were captured

the required criteria. Regarding the evaluation, SPI expert may interpret the questions in the questionnaire differently, also the questions which should reflect the criteria of the models in order to evaluate these models, a pilot study was done to mitigate this two limitations. In addition, the questions might not capture the opinions of the experts. So, we add one open-ended question to describe their comments.

6.2 Conclusion & Future Work

In this thesis, we have proposed two models for implementing CMMI level 2 specific practices SP 1.6 "Conduct Progress Review" and SP 1.7 "Conduct Milestone Review". The models consist of templates that help understand the process. These process maps, templates are designed to facilitate the implementation of progress and milestone review specific practices of CMMI in small and medium software development organizations. In addition, initial evaluation of the models are done via an expert panel review process. As future work, the suitability of proposed models through conducting multiple case studies in industry is needed.

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APPENDIX

Stage	Action Description	Template
Initiate	• Project manager specifies the objectives for the review request. • Project manager assigns a progress review request form with a description of the project. • Reviewer receives the progress review request form to along with the baseline document of the project.	progress review Request Form.docx
Understanding	• The reviewers should understand the request and the baseline of the project • The reviewers identify the criteria in order to objectively collect the required information	

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Table 7.1 – *Continued from previous page*

Stage	**Action Description**	**Template**
Gathering Information	The reviewers need to gather the required information such as costs, quality, and schedule, commitments, stakeholder involvement and data management	
Measuring and Comparing	• The reviewer specify the measures aligned with the project objectives. • The progress is measured by those measures in order to compare it with planned one. • Compare the planned against the actual progress to see if the are any variances. • Variances may be either positive or negative, if it is negative the reviewer need to address the issues that cause the variance	measuring progress template.docx comparing progress template.docx measuring and comparing checklist template.docx

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Table 7.1 – *Continued from previous page*

Stage	**Action Description**	**Template**
Identifying issues	• The reviewer analyzes the issues and creates a detailed Impact Analysis Document. • Based on the impact the reviewer will decide either initiate the change request or just ignore the variance • The reviewer might ask the project manger to decide triggering the change request or not by quantifying the impact on the progress. • The project manger may hold meeting to solve the problems or issues. • Once the change request is initiated analyzing the impact, categorizing and prioritizing change requests are needed. •	Change request.docx

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Table 7.1 – *Continued from previous page*

Stage	**Action Description**	**Template**
Tracking corrective action	• Track change request by checking its status. • When the problem is not solved the reviewer should inform the project manger. • The meeting is held by the project manger to discuss other options. • When the problem is solved the reviewer will update the status of change, plan, and estimate. • The reviewer should document the results of review. • The reviewer should communicate the results with project manger • The project manger will ask for approval from stakeholder before proceeding further.	Template

Continued on next page

Table 7.1 – *Continued from previous page*

Stage	**Action Description**	**Template**

Table 7.1: Guideline Document of the proposed model for SP 1.6 “conduct progress review”

Stage	**Action Description**	**Template**
Initiate	• Project manager specifies the objectives for the review request. • Project manager assigns a milestone review request form with a description of the project. • Reviewer receives the milestone review request form to along with the baseline document of the project.	milestone review Request Form.docx
Understanding	• The reviewers should understand the request and the baseline of the project	
Gathering Information	The reviewers need to gather the required information about the milestone requirement	

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Table 7.2 – *Continued from previous page*

Stage	**Action Description**	**Template**
Measuring and Comparing	• Compare the planned against the actual progress regarding the requirement of identified milestone to see if the are any variances. • Variances may be either positive or negative, if it is negative the reviewer need to address the issues that cause the variance	comparing progress template.docx measuring and comparing checklist template.docx

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Table 7.2 – *Continued from previous page*

Stage	**Action Description**	**Template**
Identifying issues	• The reviewer analyzes the issues and creates a detailed Impact Analysis Document. • Based on the impact the reviewer will decide either initiate the change request or just ignore the variance • The reviewer might ask the project manger to decide triggering the change request or not by quantifying the impact on the progress. • The project manger may hold meeting to solve the problems or issues. • Once the change request is initiated analyzing the impact, categorizing and prioritizing change requests are needed. •	Change request.docx

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Table 7.2 – *Continued from previous page*

Stage	**Action Description**	**Template**
Tracking corrective action	• Track change request by checking its status. • When the problem is not solved the reviewer should inform the project manger. • The meeting is held by the project manger to discuss other options. • When the problem is solved the reviewer will update the status of change, plan, and estimate. • The reviewer should document the results of review. • The reviewer should communicate the results with project manger • The project manger will ask for approval from stakeholder before proceeding further.	

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Table 7.2 – *Continued from previous page*

Stage	**Action Description**	**Template**

Table 7.2: Guideline Document of the proposed model for SP 1.7 “conduct milestone review”

Change Request

Project Name:

Change Req. No:

Date:

Priority:

Status of the Request:

Detailed Description of Proposed Change:

Justification for Proposed Change:

Impacts of Change:

Comments:

Figure 7.1: The template of change request

Progress Review Request

A) General Information

Project Title:	
Date Prepared:	
Project Manager:	
Request No.	
Team Members Names	
Reviewing Period	**From To**

B) Brief Description about the project

C) Objective of the Progress Review

Figure 7.2: The Template of progress review request

Measuring The Progress

A) General Information:

Date of Report:	
Submitted to:	
Project Name:	
Project Number:	
Progress Review Number:	
The Source of Data:	
Project Manager:	
Project Team Member Names:	

B) Measure The Actual Progress:

Progress Review Criteria	Progress Measures Used	Units of Measures	Brief Description about the measure

C) Comments:

Figure 7.3: The template of measuring step

Comparing Step

Project Title:	
Date Prepared:	

Schedule Comparison: -

Planned Schedule	Actual Schedule	The variance

Quality Comparison: -

Planned Quality	Actual Quality	The variance

Budget Comparison: -

Planned Budget	Actual Budget	The variance

Root Cause: -

Figure 7.4: The template of comparing step

Measuring and Comparing Checklist

Date of Report:	
Submitted to:	
Project Name:	
Project Number:	
Progress Review Number:	

No.	Question	Response	Comments
1	Are measures of performance clear?		
2	Do we have clear vision about the baseline?		
3	Does the difference between planned actual need to initiate change request?		
4	Are measures of performance fit to the project?		
5	Have we gathered the required information?		
6	Are the chosen measures consistent with the objective?		
7	Do we have planned milestone to compare?		

Name: ……..

Signature: …….. **Date: ……..**

Figure 7.5: The template of measuring and comparing checklist

1. **Current Position** *

2. **Please rank your knowledge about Capability Maturity Model Integration (CMMI) by circling a response on the following scale: using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all"** *
   Mark only one oval.

   - 1
   - 2
   - 3
   - 4
   - 5

3. **How many years of industry experience do you have in Software Process Improvement projects?**

4. **Please specify the size of your organization.** *
   Mark only one oval.

   - Small
   - Medium
   - Large
   - Not sure

5. **Please specify the number of employees in your organization.** *
   Mark only one oval.

   - Less than 20
   - between 20-60
   - between 61-100
   - Greater than 100

1) The proposed model for SP 1.6 satisfied the goal of the specific practice, according to CMMI v1.3 specifications which is "Periodically review the project's progress, performance, and issues"? *

Mark only one oval.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree

2) How clear is the representation of our proposed model for SP 1.6 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all" *

Mark only one oval.

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

3) How much knowledge of CMMI is required to learn how to use our proposed model for SP 1.6 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all" *

Mark only one oval.

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

4) How useful would it be to the software industry to use our proposed model for SP 1.6 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all" *

Mark only one oval.

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

5) The use of our proposed model for SP 1.6 would improve the software process and lead to the production of high-quality software products. *

Mark only one oval.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree

Figure 7.7: Evaluation form of proposed model for SP 1.6

6) The use of our proposed model for SP 1.6 would help mange the progress review during the project *

Mark only one oval.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

7) The use of our proposed model for SP 1.6 would maintain customer satisfaction in targeting their needs. *

Mark only one oval.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

8) Our proposed model for SP.1.6 is applicable to small and medium software development organization. In other words, it can be applied to both small and medium software development organization. *

Mark only one oval.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

9) please provide us with comments on how we could improve our proposed workflow model for SP 1.6 .

Figure 7.8: Evaluation form of proposed model for SP 1.6

1) The proposed model for SP 1.7 satisfied the goal of the specific practice, according to CMMI v1.3 specifications which is "Review the project's accomplishments and results at selected project milestones" ? *

Mark only one oval.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree

2) How clear is the representation of our proposed model for SP 1.7 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all" *

Mark only one oval.

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

3) How much knowledge of CMMI is required to learn how to use our proposed model for SP 1.7 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all" *

Mark only one oval.

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

4) How useful would it be to the software industry to use our proposed model for SP 1.7 ? using a scale of 1 to 5, with 5 = "very" and 1 = "'not at all" *

Mark only one oval.

- ◯ 1
- ◯ 2
- ◯ 3
- ◯ 4
- ◯ 5

5) The use of our proposed model for SP 1.7 would improve the software process and lead to the production of high-quality software products. *

Mark only one oval.

- ◯ Strongly Agree
- ◯ Agree
- ◯ Neutral
- ◯ Disagree
- ◯ Strongly Disagree

Figure 7.9: Evaluation form of proposed model for SP 1.7

6) The use of our proposed model for SP 1.7 would help mange the milestone review during the project *

Mark only one oval.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

7) The use of our proposed model for SP 1.7 would maintain customer satisfaction in targeting their needs. *

Mark only one oval.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

8) Our proposed model for SP.1.7 is applicable to small and medium software development organization. In other words, it can be applied to both small and medium software development organization. *

Mark only one oval.

- Strongly Agree
- Agree
- Neutral
- Disagree
- Strongly Disagree

9) please provide us with comments on how we could improve our proposed workflow model for SP 1.7 .

Figure 7.10: Evaluation form of proposed model for SP 1.7

Vitae

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